Wireless Temperature Control Plant Model Using LabVIEW

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ABSTRACT

This paper presents a wireless temperature control plant. The proposed system consists of RTD PT1000 temperature sensor, Wheatstone bridge circuit, amplifier circuit, ESP32 module, SCR power regulator, incandescent lamp, and LabVIEW program for controlling and monitoring temperature of plant. The RTD PT1000 sensor is used for measuring the temperature of plant and converting to voltage by Wheatstone bridge circuit before sent the output voltage to analog input port of ESP 32 module. The TCP/IP protocol is used to communicate between LabVIEW program and ESP32 module via WIFI network. LabVIEW program is employed to monitor and control temperature of plant via display screen. The experimental testing with various conditions shows that the proposed system can monitor and control temperature of plant with satisfactory values without the cables connecting between the temperature plant and the control unit.

CCS CONCEPTS

• **Hardware**; • **Communication hardware**; • **interfaces and storage**; • **Sensor devices and platforms**;

KEYWORDS

Temperature Control, Wireless system, TCP/IP protocol, ESP32 module

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1 INTRODUCTION

Nowadays, wireless sensor technology is developing rapidly. Wireless sensors can be used in various applications, such as agricultural monitoring and control system, industrial control and process monitoring, healthcare and biomedical applications, and food industry [1-3]. For temperature control is a process that changes the temperature of a controlled area by transfer heat energy into or out of a controlled area to obtain the setting temperature. This process is important and highly used in many industries such as heat-treating applications, packaging applications, plastics industry, healthcare industry, chemical processing, food and beverage industry. Several methods for controlling temperature in industrial processes are proposed such as proportional control, proportional-integral-derivative control (PID), on-off control and fuzzy logic control [4-8].

This paper presents the method to design and implement a low cost wireless temperature control plant which is used for study of wireless system and temperature control techniques. The aim of this proposed wireless temperature control plant design is to be low cost, small size, easy-to-use, portable and wireless system.

2 THE PROPOSED SYSTEM

This paper presents the design and realization of a wireless temperature control plant used for study of wireless system and temperature control techniques. The proposed system consists of temperature sensor, Wheatstone bridge, amplifier circuit, ESP32 board, SCR power regulator and PID controllers. The RTD PT1000 sensor is used for measuring the temperature of plant and converting to voltage by Wheatstone bridge circuit. The amplifier circuit is used for amplifying and sending the signals to LabVIEW program via the ESP32 module as an intermediary to communicate wirelessly over the internet network using Transmission Control Protocol/Internet Protocol or TCP/IP. This protocol is a set of communication protocols used to connect between network devices on the internet. In this system, TCP/IP protocol is used to communicate between LabVIEW program and ESP32 module. The PID controller function in LabVIEW is used for controlling temperature of the plant. The display screen is developed by LabVIEW program for monitoring and setting parameters via screen monitor. The output of PID controller is sent to the SCR power regulator for controls the brightness of the incandescent lamp. The temperature in the plant is proportional to the brightness of lamp. Figure 1 shows the proposed wireless temperature control plant.

2.1 Resistance temperature detector

Resistance temperature detector (RTD) is the temperature sensors that changes the resistance value corresponding to the measured temperature. RTD sensor is usually constructed of platinum with positive resistance temperature factor. This sensor is high accuracy and stability compared to another temperature sensor. In this proposed system, RTD sensor type PT1000 is used for measure temperature of process plant. The value of sensor resistance, PT1000,

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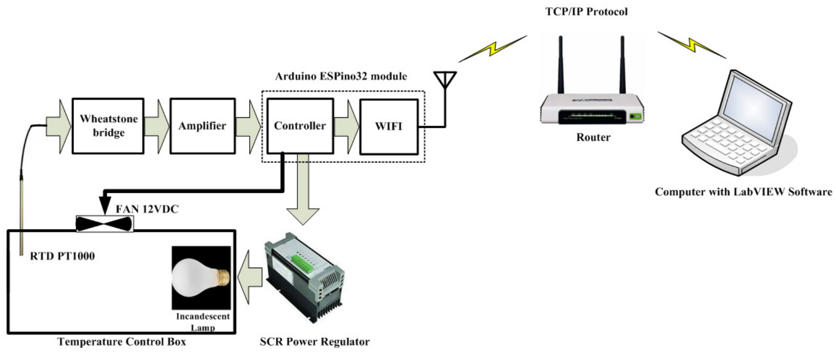

Figure 1: The proposed wireless temperature control plant.

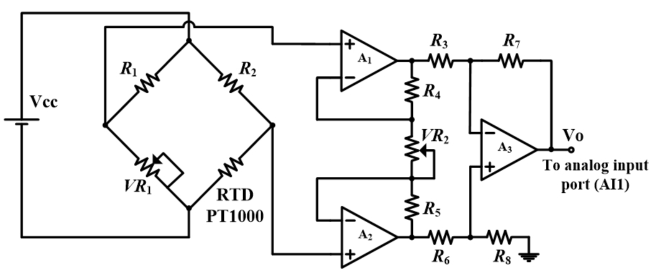

Figure 2: The RTD PT1000 sensor, Wheatstone bridge and amplifier circuit.

is 1000 ohm at temperature 0°C with nominal resistance variation by 3.85Ω/°C.

2.2 Wheatstone bridge and amplifier circuit

From the Figure 1, the proposed wireless temperature control plant uses RTD PT1000 sensor for measuring the temperature of temperature control box. The Wheatstone bridge and amplifier circuit are used for converting resistance of RTD PT1000 to output voltage. Figure 2 shows the RTD PT1000, Wheatstone bridge and amplifier circuit.

The output voltage Vo is directly proportional to the temperature of proposed system as (1).

$$V_0 = V_{cc}\left(\frac{R_{RID}}{R^2 + R_{RTD}} - \frac{VRI}{R1 + VRI}\right)\left(1 + \frac{2R4}{VR2}\right) \tag{1}$$

To demonstrate the circuit performances of the proposed Wheatstone bridge and amplifier circuits, the schemes in Figure 2 were implemented using op-amps LF351. The RTD PT1000, the resistors R1 = R2 = 1kΩ, potentiometer VR1 = 2kΩ, resistors R3 = R4 = R5 = R6 = R7 = R8 = 100kΩ, and potentiometer VR2 = 20kΩ were chosen. The supply voltage (Vcc) is set to 12V. In order to test the performance of proposed circuit, we adjust the temperature of temperature control box from 30 to 60 °C. Table 1 shows the measurement voltage of the circuit in Figure 2.

2.3 ESP32 Module

ESP32 module is a low-cost microcontroller integrated Wi-Fi transceiver and dual-mode Bluetooth. It is designed for portable

Table 1: The measurement voltage of the proposed circuit in Figure 2

Temperature of temperature control box (°C)	Vo (Volt)
30	0
40	1.12
50	2.20
60	3.30

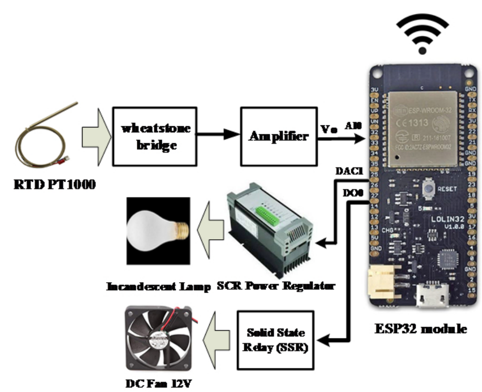

Figure 3: The connection diagram of ESP32 module.

devices, wearable electronics, low-power consumption devices, and suitable for use in Internet-of-Things (IoT) technology. ESP32 module is widely used in industrial monitoring and home automation such as smart power plugs, smart lighting, Wi-Fi enabled speech recognition devices, baby monitors, and wireless data collection. Many researchers propose the applications of ESP32 module in industrial monitoring and home automation [2-5]. For this system, ESP32 module is used to send temperature data to LabVIEW program and receive control data from LabVIEW program via Wi-Fi by TCP/IP protocol.

2.4 SCR Power Regulator

SCR power regulator is use for controlling the output of power supply. It is most often used to control the power supply of the

Table 2: The control voltage, output voltage and Incandescent lamp power

Control voltage (VDC)	Output Voltage (VAC)	Incandescent Lamp Power (Watt)
0	0	0
1	51.2	23.3
2	116.9	53.1
3	175.2	79.5
4	205.7	93.5
5	219.1	99.6

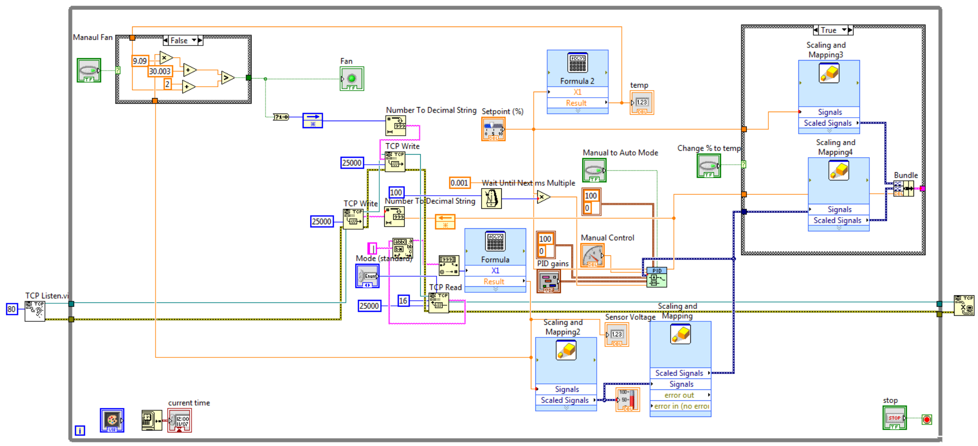

Figure 4: The block diagram of LabVIEW program used in proposed system.

heater or incandescent lamp. For this system, SCR power regulator is used for controlling the brightness of incandescent lamp via the control voltage. The signals of control voltage, output voltage and Incandescent lamp power are shown in Table 2.

2.5 LabVIEW Program

The proposed system uses LabVIEW program as a temperature controller. It receives the temperature or process variable PV from RTD PT1000 sensor and sends manipulate value MV to the control device (SCR power regulator and incandescent lamp) via Wi-Fi by TCP/IP protocol. The PID function in LabVIEW program is used for control temperature of the temperature control box. The display screen of the proposed system is created that corresponds to the parameters of the PID function in LabVIEW which contains the part that receives the value from the user such as mode of operation, the Set-point (SP), the Integral time (Ti), Derivative time (Td), Proportional gain (Kc), and manual fan control switch (on-off). The display screen shows the temperature level of the plant in degree Celsius °C and graph of process values such as Set-point SP, Process variable PV and Manipulate variable MV in percentage (%) corresponding to time.

2.6 Data Flow of Proposed System

The concept of data flow between input and output signals of the proposed wireless temperature control plant can be shown as Figure 6.

Figure 6 shows the data flow of proposed system. Firstly, the RTD PT1000 sensor is used to convert the temperature of process plant to resistance with linear relationship. The resistance of RTD PT1000 sensor is converted to voltage and sent to amplifier for amplifying voltage before sent to ESP32 module via analog-to-digital converter (ADC) at input port. The voltage of ADC corresponding to temperature of process plant state as process variable PV is sent to PID function of LabVIEW program via Wi-Fi. The LabVIEW PID function is used to maintain the manipulate value MV to avoid errors between the process variable PV and the set-point SP required by closed-loop operation. The manipulate value MV is sent back to ESP32 module via Wi-Fi. ESP32 module send the control voltage in range 0-5 volts corresponding with the manipulate value MV to the input of the SCR power regulator for control brightness of incandescent lamp.

3 EXPERIMENTAL AND RESULTS

The constructed wireless temperature control plant is shown in Figure 3. The performance of the proposed system controlled by using LabVIEW program is evaluated. In the experiment, the PID parameters of PID function in LabVIEW used for the system are Kc = 30, Ti = 0, and Td = 4. We desire to adjust the temperature in two formations: increasing steps and decreasing steps. Each step is 25% of the temperature level in plant. For the increasing steps, the set-point of process value is changed from 0% to 25%, from 25% to 50%, from 50% to 75%, and from 75% to 100% with relation to

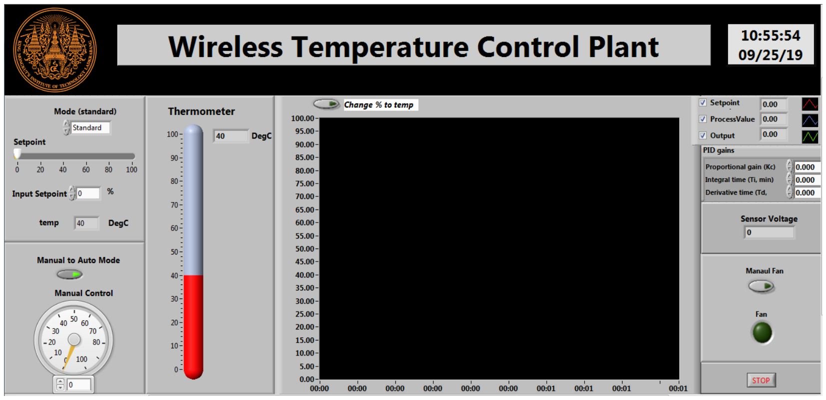

Figure 5: Display screen of the proposed system.

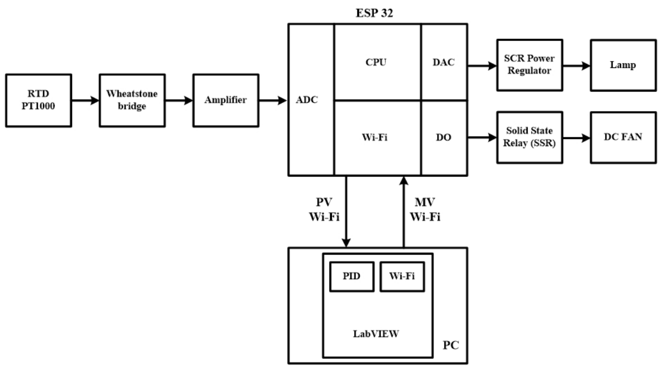

Figure 6: Data flow between input and output signals of the proposed wireless temperature control plant.

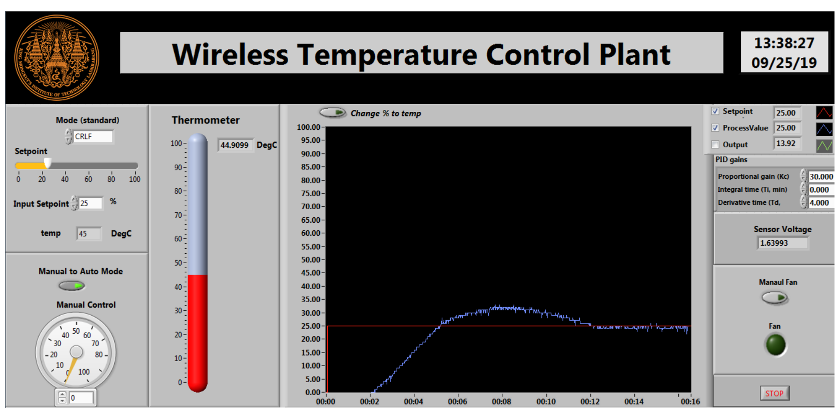

Figure 7: The display screen at process value is changed from 0% to 25%.

the temperature from 40°C to 45°C, from 45°C to 50°C, from 50°C to 55°C, and from 55°C to 60°C respectively. Similarly, for test the decreasing steps, the set-point of process value is changed from 100% to 75%, from 75% to 50%, from 50% to 25%, and from 25% to 0% with relation to the temperature from 60°C to 55°C, from 55°C to 50°C, from 50°C to 45°C, and from 45°C to 40°C respectively. Figures 7 - 10 show some display screen of the proposed system with various conditions.

The performances of the proposed wireless temperature control plant are evaluated in two parts: the settling time (minutes) and the error of the steady-state error (%).The settling time is the time required for the output temperature of the proposed system to reach and remain within a given error within 1% of set-point temperature.

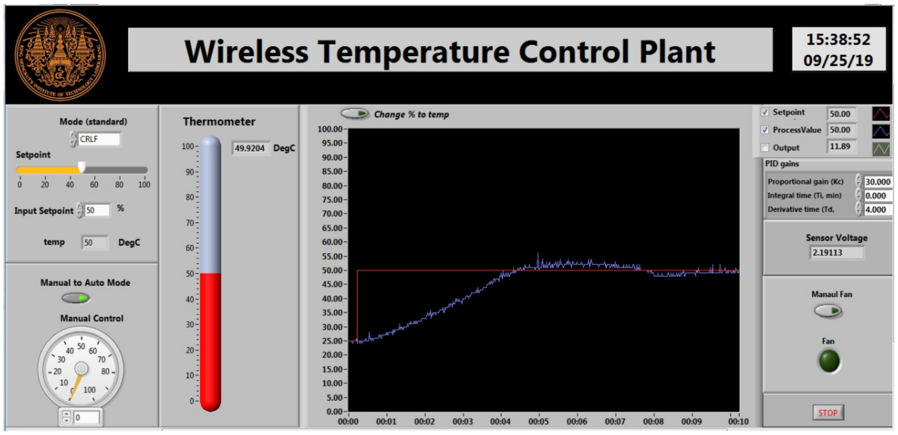

Figure 8: The display screen at process value is changed from 25% to 50%.

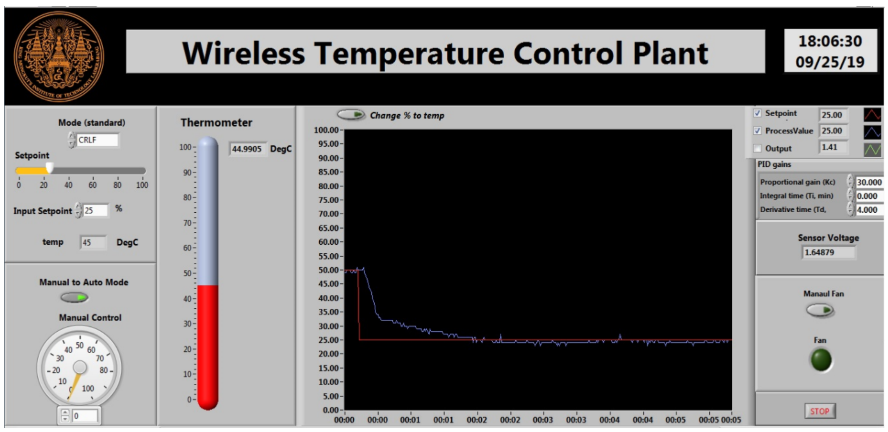

Figure 9: The display screen at process value is changed from 50% to 25%.

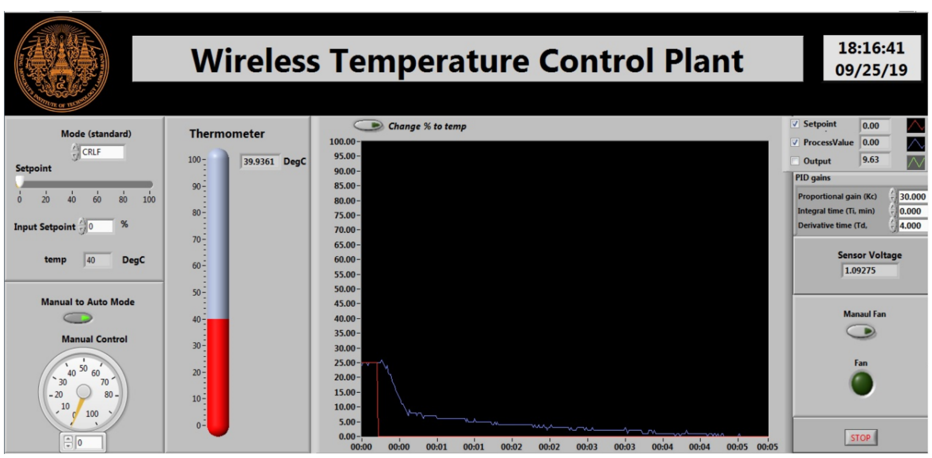

Figure 10: The display screen at process value is changed from 25% to 0%.

Table 3: The setting time of proposed system

Case	Process condition		Processrange	Temperaturerange	Settling time (Minutes)
	Increasing Step	Decreasing Step			
1	√		0-25%	40-45°C	12:31
2	√		25-50%	45-50°C	11:13
3	√		50-75%	50-55°C	9:37
4	√		75-100%	55-60°C	10:17
5		√	100-75%	60-55°C	8:16
6		√	75-50%	55-50°C	6:29
7		√	50-25%	50-45°C	5:39
8		√	25-0%	45-40°C	5:23

Table 4: The error between set-point and process value

Case	Process condition		Processrange	Temperaturerange	Steady-state error (%)
	Increasing Step	Decreasing Step			
1	√		0-25%	40-45°C	0.22
2	√		25-50%	45-50°C	0.16
3	√		50-75%	50-55°C	0.12
4	√		75-100%	55-60°C	0.11
5		√	100-75%	60-55°C	0.03
6		√	75-50%	55-50°C	0.19
7		√	50-25%	50-45°C	0.02
8		√	25-0%	45-40°C	0.16

The resulting setting time and steady-state error of the proposed system using the PID controller of LabVIEW program are shown in Table 3 and Table 4, respectively. The results in Table 3 show that the set-point of process value in decreasing step case has settling times shorter than the set-point of process value in increasing step case. Table 4 shows the results of the steady-state error of the plant using the PID controller of LabVIEW program. The results of the proposed system have error less than 0.5% of the set-point of temperature in both cases (increasing step and decreasing step).

4 CONCLUSIONS

In this paper, the wireless temperature control plant using LabVIEW has been proposed. The implemented wireless temperature control plant consists of RTD Pt1000 temperature sensor, Wheatstone bridge circuit, amplifier circuit, ESP32 module, SCR power regulator, incandescent lamp and LabVIEW program for controlling and monitoring temperature of plant. The experimental testing with various conditions showing the proposed system can control and monitor temperature of plant with satisfactory value.

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